BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY.
Vol. XII. Article X. March, 1904.

THE YELLOW OCHER-DEPOSITS OF THE CARTERSVILLE DISTRICT, BARTOW COUNTY, GEORGIA.[1]

By THOMAS LEONARD WATSON.

CONTENTS.

INTRODUCTION, ... 199
HISTORICAL STATEMENT, ... 200
GEOLOGY OF THE DISTRICT, ... 201
The Weisner Quartzite, ... 203
Topography, ... 205
Rock Weathering, ... 207
THE OCHER-DEPOSITS, ... 208
Petrography of the Quartzite, ... 209
Associated Ore-Deposits, ... 211
Chemical Composition of the Ocher, ... 212
Mode of Occurrence of the Ocher, ... 213
In the Fresh Rock, ... 214
In the Residual Clays, ... 215
Origin of the Ocher, ... 216
ECONOMIC FEATURES, ... 218
Methods of Mining, ... 218
Preparation of the Ocher, ... 218
Uses, ... 221

INTRODUCTION.

Knowledge of the existence of yellow ocher-deposits in Bartow county, Georgia, dates back to the early mining of manganese- and iron-ores in the vicinity of Cartersville. Systematic mining of the ocher in this area really began, however, probably not longer than a decade back, although the date of its first working is as early as the year 1877. The district has been, for a number of years, one of the principal producers of yellow ocher in the United States; and at no period of its development have mining activities been greater and more successful than at present.

---

[1] Published by permission of the State Geologist of Georgia.

Reprinted from *Transactions of the American Institute of Mining Engineers.* (New York Meeting, October, 1903.)

Systematic field-study of the ocher and manganese-deposits of Georgia was begun by me while I was a member of the State Geological Survey, late in the season of 1900; and completed during the field-season of 1902. Separate reports on these deposits are in course of preparation, and as soon as completed they will be published as bulletins of the State Survey. It is the object of this paper to present some of the more important facts brought out in the field and laboratory study of the ocher-deposits of Bartow county, Georgia.

Historical Statement.

The first authentic record of ocher mined in Bartow county, Georgia, was in the year 1877, when Mr. E. H. Woodward began mining it on a property located near the limits of the town of Cartersville. The crude ocher as mined was hauled in wagons to Cartersville and there prepared for market. Mr. Woodward was engaged at the same time also in mining manganese-ores on the Dobbins property, six miles northeast of Cartersville.

Mining of the ocher on a small scale was continued on this and the adjoining property until 1890, when the Georgia Peruvian Ocher Co., supported by Western capitalists, became the owner of the property, and improved methods in the preparation of the ocher for market were introduced. Hauling to Cartersville was discontinued on account of the roads, and a plant for preparing the ocher was located at Emerson, two miles south of the mines. The first shipment of American ocher to Europe is reported to have been made in December, 1890, from the Cartersville mines, a consignment of 50 tons having been shipped to England.[1]

In 1890, two experienced ocher-men from the East, Mr. J. C. Oram of Vermont and Mr. E. P. Earle of New York, became interested in the company, and modern machinery and improved methods were brought into use. Mr. Oram was the first to introduce in the district the natural process of air-drying (sun)

[1] *Mineral Resources of the United States for* 1889 *and* 1890, p. 509.

in vats dug in the ground. The ocher-industry in Georgia properly dates from this year.

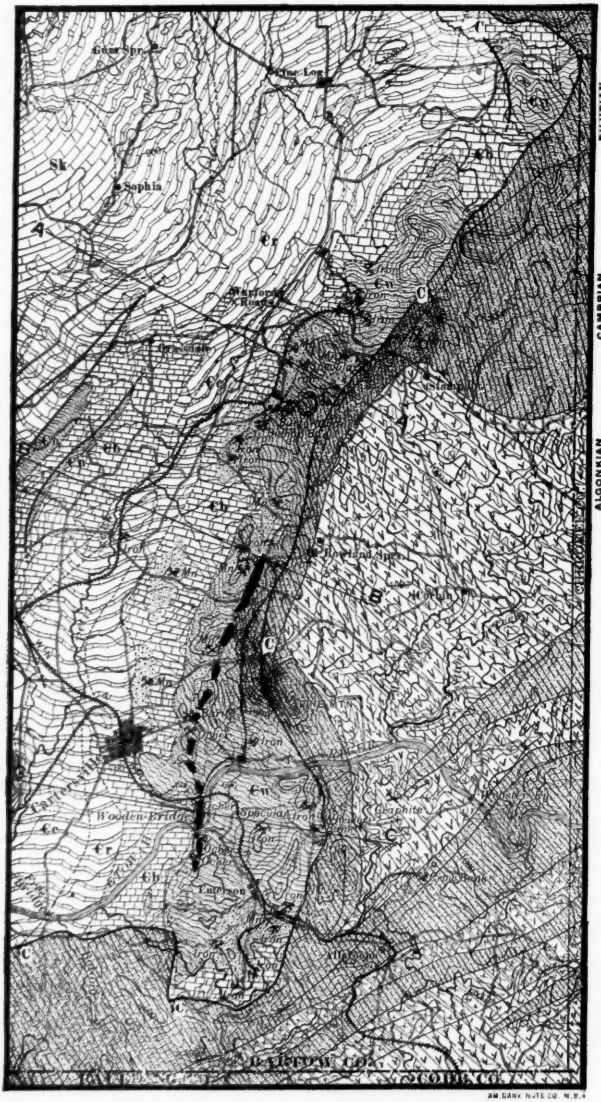
At present, four plants of large size and thoroughly equipped are engaged in mining and shipping the ocher in the Cartersville district: namely, the Georgia Peruvian Ocher Company; the Cherokee Ocher & Barytes Company; the Blue Ridge Ocher Company; and the American Ocher Company. The last plant was added in 1902. In every instance the mill for preparing the ocher is located at the mines, thereby reducing the cost of production from what it was in the early period, when mine and mill were separated by a considerable distance. The present plants are all located within two-and-a-half miles of the town of Cartersville, which is the shipping point.

Several unsuccessful attempts have been made to produce ocher at Rockmart, in the adjoining county, Polk, on the southwest, but each time the venture was abandoned.

Geology of the District.

The area here described, as shown on the accompanying map, Fig. 1, is limited to the southeastern portion of Bartow county, in northwestern Georgia; and it lies in the vicinity of the town of Cartersville, from which the district derives its name. It is one of the most productive ore-districts in the Southern Appalachians. Stratigraphically, the area is nearly equally divided between the Paleozoic formations on the west and the older crystalline metamorphic rocks of the Piedmont plateau and the Appalachian mountains on the east. The irregular line separating the two groups of unlike rocks marks the position of the Cartersville fault, which is the most important structural feature in the region.

As indicated in Fig. 1 (C, C, C, C), the rocks belong to two geologically distinct groups, which show marked differences as to age and kind. To the west of the fault-line the rocks are sedimentaries, and include quartzites, sandstones, shales, and limestones of Cambro-Silurian age. To the east of the fault-line the rocks are metamorphic crystallines, derived in part from original igneous masses and in part from original sediments.



Geological Map of the Cartersville District, Georgia, Showing the Distribution of the Ore-Deposits. (C. W. Hayes, *Trans.*, xxx., 405.)

Over parts of the area it is difficult to state definitely whether the original rock was igneous or sedimentary in origin. The altered sediments include conglomerates, slates, schists, and probably some of the gneisses. Wide variation in composition, and to a less extent structure, characterize the intrusive rocks, ranging from extremely basic rocks of the diabase type to acid granites, with perhaps diorite as the most common type. These igneous masses are no longer composed of massive rocks in structure, but, on account of intense pressure-metamorphism, they are now rendered highly schistose. On account of the absence of fossils in the sedimentaries of this series, and because of the rocks having every appearance of extreme age, Hayes has grouped them as Algonkian (Ocoee) in age.

The rock-sequence for the Paleozoic formations on the west side of the fault-line, named in descending order, becomes:

Silurian,	. . .	4. Knox dolomite.
Cambrian,	. . .	3. Rome and Conasauga shale. 2. Beaver limestone. 1. Weisner quartzite.

Of these formations only the Weisner quartzite is ocher-bearing and is of importance in the present connection, hence no description of the other formations will be given in this paper.

The Weisner Quartzite

The yellow ocher-deposits of the Cartersville district are limited exclusively to the Weisner quartzite. As shown on the map, the principal area of the quartzite forms a continuous narrow belt, approximately 15 miles long and several miles wide, in the central portion of the area mapped. Its eastern limit is the Cartersville fault, which marks the contact of the formation on the east with the rocks of the Ocoee series. Near the middle western margin of the map, faulting has exposed two additional narrow strips or bands of the quartzite, which are marked by the entire absence of ocher. As nearly as can be estimated the thickness of the quartzite in this area does not exceed 2,000 feet.

Lithologically, the formation is not entirely uniform, but in places it shows considerable variation, both in composition and texture, and in color as well. It is composed principally of a compact, fine-grained vitreous quartzite varying from light to dark gray in color, and in places containing beds of fine-grained conglomerate. Intercalated beds of a drab to darker colored siliceous shales of varying thickness, much crumpled, contorted and altered in places, are often met with. The formation contains much pyrite in the form of grains and crystals in places, and this mineral seems to be equally abundant in both the quartzite proper and the interbedded shale layers. The two mineralogically-unlike beds, shale and quartzite, are likewise ocher-bearing, and the difference in composition of the rock serves as a basis for making two grades of the ocher. The ocher found replacing the shales is prevailingly darker in color, because of the large proportion of admixed argillaceous or clayey matter derived from the shales, which cannot be separated from the refined ocher; while the ocher found replacing the quartzite proper is uniformly lighter in color, because of less admixed clay.

The effects of intense pressure-metamorphism are plainly evident in all parts of the quartzite formation, as shown in Fig. 3. As a result of the action of the compressive forces the quartzite layers have been sharply folded, and in addition the formation has been extensively crushed and shattered over most of its parts, especially in the ocher-bearing portions. So extensively crushed and shattered is the quartzite as indicated in some of the sections of the larger ocher-openings in the area, that it is almost impossible to determine the original bedding of the rocks. As often shown by its brecciated condition, the quartzite is presumably cut by numerous faults, but such lines of fracture, if they exist, have not been traced. As Hayes has stated, the physical forces were probably attended by increased chemical action, inferred from the formation of the ocher.

The composition of the quartzite proper is shown in the chemical analysis below made by the N. P. Pratt laboratory, in

Atlanta, Georgia, of specimens of the rock collected by me from different exposures of the formation.

	Per Cent.
Silica,	90.36
Alumina,	1.52
Iron sesquioxide,	0.57
Iron disulphide,	1.50
Lime,	0.27
Magnesia,	0.27
Soda,	0.43
Potash,	0.16
Manganese oxide,	none
Titanic oxide,	0.07
Barium sulphate,	4.46
Water,	0.31
Total,	99.92

Attention is called in the analysis to the percentages of iron disulphide (pyrite) and barium sulphate (barite) present in the rock. The occurrence of pyrite in the rock has been referred to above. The mineral barite is present to a greater or less extent in all the ocher-deposits of the district, but its presence in the fresh rock as a mineral constituent is nowhere indicated, either macro- or microscopically. The very small percentages of lime and alkalies shown in the analysis confirms the microscopic study of a large number of thin sections of the rock, in the nearly complete absence of feldspars. A few thin sections, however, showed sporadic grains of both microline and a striated plagioclase.

Topography.

With respect to surface configuration, the district may be divided into two nearly equal, unlike areas, as indicated on the accompanying map, Fig. 2. The line separating these two areas is an irregular one roughly paralleling the fault-line, and located from one to three miles west of it, and marking the contact between the Weisner quartzite and the Beaver limestone. The contour lines on the map, Fig. 2, mark off quite strongly the dividing-line between the two unlike areas.

That part of the district north of the Etowah river and

west of a line drawn northeastward through Cartersville marks a rather smooth plain, etched out of the soft shales and limestone of Cambrian age. Its average elevation above mean sea-level is between 800 and 900 ft. Slight inequalities in the form of irregular hills or minor ridges, rising from 100 to 125 ft. above the general surface of the plain, denote unreduced areas. Elevations of less than 800 ft.—from 750 to 775 ft.—are recorded in places along some of the larger stream-courses. Westward, the plain grades into the Knox dolomite plateau, a slightly more resistant magnesian limestone, whose general average elevation is but little above that of the Cartersville portion of the Paleozoic plain.

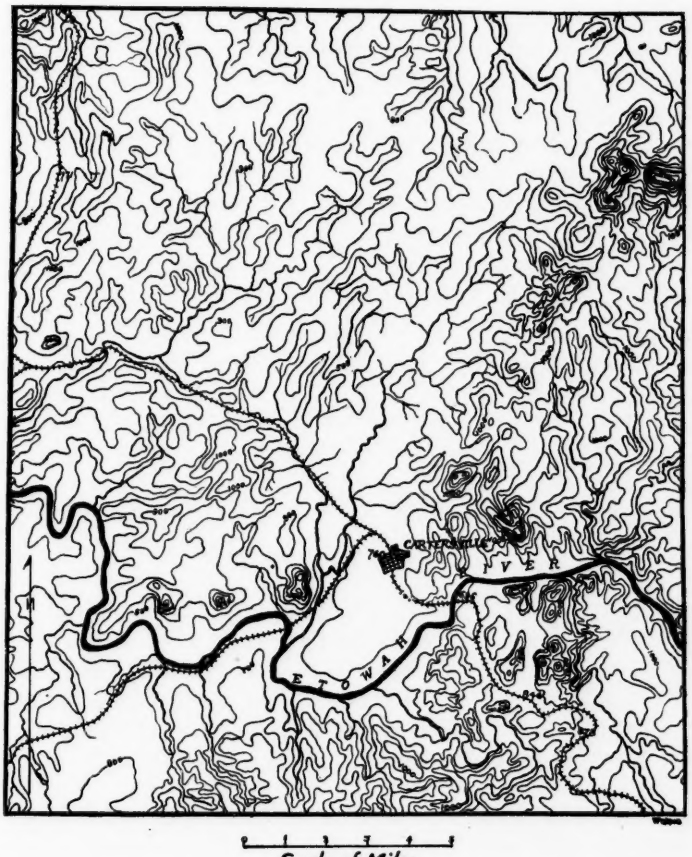
Beginning with, and including, the long central band of Weisner quartzite, that part of the mapped area to the south of the Etowah river and east of the plain already defined, is a second area whose surface is higher than that of the Paleozoic plain described and in marked contrast to it. The larger portion of this area forms the northwestward extension of the Piedmont plateau. Its general surface-elevation will average less than 1,000 ft. above mean sea-level, with numerous residuals in the form of irregular hills and ridges standing several hundred feet above the plateau surface. The surface then is an irregular one, trenched by comparatively deep and narrow stream-channels, in many places cut through the thick covering of decayed rock into the hard rock beneath. The northeast corner of the mapped area forms the equivalent lowering portion of the Appalachians, showing elevations of from 1,800 to 2,000 ft. This marks the roughest surface in the district. The higher and more roughened surface of the eastern half of the mapped area is etched out of geologically old, highly-tilted and disturbed metamorphic crystalline rocks, whose age for the most part is pre-Cambrian.

The entire district covered by the map is well watered. Its drainage is through numerous nearly north- and south-flowing streams tributary to the Etowah river, the master stream of the region, which has a general westward course, passing within a short distance south of the town of Cartersville.

Rock-Weathering.

The rocks of the area are very generally buried under a considerable thickness of residual clays derived from the decay of the underlying rocks by the usual action of the atmospheric

FIG. 2.



Topographical Map of the Cartersville District, Georgia. (Cartersville Topographic Sheet, *U. S. Geol. Survey.*) Contour-interval, 100 ft.

agents. Over many parts of the region exposures of the fresh

rock are seldom seen. A thickness of 100 ft. and more of the residual decay is frequent over the district. Difference in composition of the sub-terranes shows equally as marked a difference in the chemical and physical properties of the derived decay. The decay derived from the limestone is usually a deep-red ferruginous clay with or without admixed chert fragments, as the original rock was chert-bearing or not. That derived from the harder and more resistant quartzite is a light gray siliceous clay, in which the proportion of clay is usually relatively smaller than that derived from the sandstone. So strongly marked are the properties of the residual decay derived from the lithologically unlike sub-terranes, that the areas of originally fresh rock can usually be differentiated and traced with considerable accuracy by the decay.

The decay over the quartzite area is thickest in the valley-bottoms, and thinnest near and on top of the higher and steeper ridges. Along the steeper ridge-slopes exposures of the comparatively fresh and hard rock are not uncommon. On the ridge-tops large reefs and broken masses of the hard quartzite are frequent. The residual decay derived from the quartzite is largely admixed with fragments of various sizes of the quartz-rock in all stages of decay, from partially discolored hard rock to masses of loose or incoherent quartz-grains or sand.

The Ocher-Deposits.

As indicated on the the accompanying map, Fig. 1, the ocher belt has an approximate length of about eight miles in a nearly north-south direction. Traced by the outcroppings and the prospect-openings the belt is a very narrow one, not exceeding perhaps two miles in the widest point. It has its southernmost extension at and to the west of Emerson, about two miles south of the Etowah river, and is traced in a northward direction, about one mile east of Cartersville, to a point north and to the west of Rowland Springs. Beyond this point surface-indications disappear and no prospect-openings have been made, hence it is not possible to state definitely that this marks the extreme limit of the belt to the north.

Petrography of the Quartzite.

Some portions of the Weisner quartzite, as previously stated, contain interbedded siliceous shales of dark color. The quartzite proper varies from dense, nearly white, and vitreous massive beds, without distinct evidence of its fragmental character visible to the unaided eye, to massive beds of distinct granular quartzite of light and dark gray colors. By far the majority of the beds are composed of the granular quartzite in which the fragmental character is plainly evident. In the granular type the rock varies from an even-grained, fine-granular quartzite to a distinct conglomerate facies, in which the quartz-pebbles are usually of very small size.

Thin sections show it to be a rather pure quartz rock, composed of quartz-grains of somewhat variable size. In general the larger grains contain some inclusions of foreign mineral matter. Hardly a section examined failed to show, in a number of the larger grains, abundant hair-like needles probably of rutile, which are often bent and curved and in many cases broken. Usually the grains are considerably clouded by very fine innumerable dust-like particles, without definite arrangement, whose exact nature it was not possible to determine. Inclusions of slender prismatic crystals of apatite are not uncommon in some of the thin sections. The general shape of the larger grains is round. When examined in detail the outer margin of the grains invariably presents an irregular, angular outline, formed by the interlocking or dove-tailing of individuals in a surrounding mosaic of much smaller quartz-granules, which fills the entire interstices between the larger grains. This mosaic of finer quartz-particles bounding the larger grains is clearly the result of peripheral shattering from compression, a circumstance which is further confirmed by the general undulous extinction of the larger grains, and by the greatly crushed condition of the formation in the field.

Besides quartz, there occurs in some of the sections a slight sprinkling of feldspar grains, including microcline and a striated plagioclase, some calcite and occasionally grains of a titanifer-

ous iron oxide. Next to quartz, pyrite is the most abundant mineral. It frequently occurs as fresh grains and crystals; more often as partially and entirely oxidized in the form of iron oxide. In the latter case the original pyrite may be altered to a limonite pseudomorph, but generally the change has been rapid and a cavity preserving the outline of the pyrite, only slightly stained or partially filled with the iron oxide, forms the only evidence of the former presence of the pyrite. The mineral, both in the fresh and in the completely oxidized or altered condition, is often present in the same thin section. The stain of yellow iron oxide derived from the oxidation of the pyrite discolors the section for some distance around and away from the position of the original sulphide mineral. The staining extends the farthest along the sutures between the quartz-grains and the fracture-lines, which are present at times in the grains.

Microscopic study shows quite plainly the relations of the ocher to the quartzite and its mode of occurrence in the rock. After a careful study of a number of thin sections under the microscope of the ocher-stained rock from different parts of the belt, my results accord so closely with Hayes's description that I quote him in full. He says:[1]

"When the transition-rock is examined under a microscope, the character of the transition can be seen even more clearly. The more compact portions, which are only slightly stained with iron, are seen to be composed of a transparent ground-mass, threaded with minute cavities, which penetrate the rock in all directions and contain a fine dendritic growth of iron oxide. The latter occurs only rarely in isolated grains, but generally in clusters of minute grains or fibers, attached to each other and branching irregularly from a central stem. They have no trace of crystal form. Passing toward the ore-body, these minute passages become larger and increase in frequency, until only a finely branching siliceous skeleton remains, the greater part of the rock having been replaced by the iron oxide. Under polarized light, the transparent ground-mass is broken up into an aggregate of small quartz-grains, penetrated in all directions by the iron oxide. The latter does not lie between the individual grains, but passes through them, as though the ground-mass were quite homogeneous. The process of replacement is never complete; for all the ocher contains more or less sand. When this is washed clean from the iron oxide, it is found to differ from ordinary sand-grains

[1] *Trans.*, 1901, xxx., 416.

in having extremely irregular outlines. This sand, as might be anticipated from the microscopic structure of the slightly altered quartzite, is evidently composed, not of the original grains of the rock, but of detached portions of the irregular siliceous skeleton, which, in the intermediate stages of replacement, holds the iron oxide in its cavities."

A chemical analysis made at the N. P. Pratt laboratory in Atlanta, Georgia, of specimens of the quartzite collected by me is given on page 205 of this paper.

The ocher occurs only in the fresh Weisner quartzite and its decay; and exposures of the fresh rock indicate that it occupies an extensively shattered zone in the formation. It is found in place in the fresh quartzite and in a similar position in the residual clays derived from the decay of the quartzite. Examples of both occurrences are abundant in the region.

Associated Ore-Deposits.

Besides ocher, the district is one of the largest and principal producers of the ores of iron and manganese in the State. In addition to these, some barite has been mined and shipped from the area. The latter mineral, while rather largely distributed over portions of the region, has not proved profitable, for the reason that it is rarely sufficiently concentrated for mining alone, and it is not of sufficient purity to make a desirable grade of marketable baryta.

The ores are often very closely associated with each other, but recent study of them shows the genesis of the types of ore-deposits to have been quite different. The deposits of yellow ocher are rarely entirely free from some admixture of one or all of the other types of ores mentioned. These are usually present only in small quantity in the ocher, and generally in sufficiently large fragments to admit of nearly complete separation from the ocher by the usual process of cleansing.

In many cases manganese oxide, in the form of very finely disseminated grains or powder, is not entirely freed from the refined product, and it is claimed that a faint greenish cast is thereby imparted to the ocher. The deposits of ocher and manganese are frequently in juxtaposition, and the openings

employed in working the manganese are now used for mining the ocher. Such occurrence is well illustrated on the property of the Blue Ridge Ocher Company, where large quantities of manganese-ores were formerly mined, and the tunnels and shafts are now utilized for removing the ocher. On the same property a large quantity of hard and porous spongy masses of limonite, occurring as lenses and irregular seams in the ocher beds, was being removed with the ocher during the summer of 1902.

At the Etowah river, on the Georgia Peruvian Ocher Company's property, several miles southeast of Cartersville, large clusters and groups of barite crystals are formed in the pockets of ocher and in the fractures and caverns of the quartzite. The barite often occurs in divergent groups of massive tabular crystals, giving crested appearance, grading into both straight and curved laminated masses.

Chemical Composition of the Ocher.

The chemical composition of both the crude and the refined ocher is shown in the table of analyses below, made by the N. P. Pratt laboratory, in Atlanta, Georgia.

Table of Chemical Analyses of the Crude and Refined Ocher.

	Samples.							
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Fe_2O_3, . . .	72.29	56.29	65.49	54.66	67.37	61.40	67.32	62.79
Al_2O_3, . . .	5.55	10.15	7.20	6.68	6.85	7.14	5.86	6.94
FeO, . . .	0.46	0.39	----	----	----	----	----	----
MnO_2, . . .	0.87	0.54	1.80	1.50	2.04	2.00	----	----
SiO_2 (free sand), .	6.65	8.94	7.76	17.42	6.54	11.89	9.14	6.20
SiO_2 (combined as silicates), . . .	3.98	9.49	6.85	10.08	6.61	5.84	6.35	9.78
H_2O at 105° C, . .	0.55	2.08	0.40	0.48	0.96	0.46	0.78	0.50
H_2O above 105° C, .	9.22	11.34	10.50	9.24	9.63	9.37	9.60	----
Total, . .	99.57	99.22	100.00	100.00	100.00	100.00	99.05	----

I. Crude ocher from Mansfield Brothers' property. Lot No. 462, 4th District, 3d Section, Bartow county, Georgia.

II. Crude ocher from the John P. Stegall property, near Emerson, Bartow county, Georgia.

III, IV, V and VI. Refined ocher from the Blue Ridge Ocher Company's property. Lot No. 490, 4th District, 3d Section, Bartow county, Georgia. Furnished by courtesy of the Manager, Captain John Postell, Cartersville, Georgia.

VII. Refined ocher from the Cherokee Ocher & Barites Company's property, one mile east of Cartersville. Furnished by courtesy of the President, Mr. T. W. Baxter, Atlanta, Georgia.

VIII. Refined ocher from the American Ocher Company's property. Lot No. 475, 4th District, 3d Section, Bartow county, Georgia. Furnished by courtesy of the Manager, Mr. Waite, Cartersville, Georgia.

The analyses are sufficiently explanatory, and attention need only be called to one feature, namely, the high percentage of ferric oxide. Assuming all the ferric oxide to be combined with water[1] in the proportion to form limonite, and calculating on this basis the percentage amount of limonite in each analysis, we find an average of 78.33 per cent. for the eight analyses. This means that about one-fourth of the entire product consists of foreign mineral matter, in the form of impurities that cannot be separated from the hydrous iron oxide (ocher) by the present methods of cleansing. Field- and laboratory-studies show this admixed mineral matter to consist largely of clay and very finely divided quartz-particles, with, in many cases, smaller amounts of manganese oxide. Notwithstanding these facts the yellow ocher of the Cartersville district is one of the very best mined in the United States, and is the equal of most of the foreign ochers of this color.

Mode of Occurrence of the Ocher.

As previously defined, the yellow ocher belt in Bartow county is entirely limited to the Weisner quartzite of lower Cambrian age. Field-study shows that the ocher occurs in both the hard and fresh quartzite and in the residual clays derived

[1] Only in one case, analysis II of the table, is there sufficient water indicated in the analyses to satisfy all of the ferric oxide according to the formula $2Fe_2O_3 \cdot 3H_2O$.

from the decay of the quartzite. So far as mining developments have been made in the area, the ocher has nearly equal occurrence in the fresh and in the decayed quartzite. At every point examined, its position in the residual clays is in all respects similar to that in the hard and fresh rock. Its occurrence in the fresh and in the altered rock can best be described separately.

Occurrence in the Fresh Rock.—Abundant opportunity is afforded for studying the mode of occurrence of the ocher in the fresh rock over many parts of the area, from the good natural exposures of the rock. (See Figs. 4, 5 and 6.) For the study of the ocher in its relations to the fresh rock, the best section is at the wooden bridge over the Etowah river, two miles southeast of Cartersville, where the river has cut across one of the quartzite ridges and where extensive mining has been done by the Georgia Peruvian Ocher Company. Here the quartzite has been extensively crushed and shattered from compression, so that it is difficult to determine the original bedding of the rock (Fig. 4).

Concerning the occurrence of the ocher at this locality, Doctor Hayes says:[1] "The ocher forms a series of extremely irregular branching veins, which intersect this shattered quartzite without any apparent system. They frequently expand into bodies of considerable size; and when the ocher is removed, rooms from 6 to 10 ft. in diameter are sometimes left, connected by narrow winding passages. The mining of the ocher has left the point of the ridge completely honey-combed with these irregular passages and rooms.

"The contact between the ocher and the inclosing quartzite is never sharp and distinct, but always shows a more or less gradual transition from the hard vitreous quartzite, to the soft ore which may be easily crushed between the fingers. The quartzite first becomes stained a light yellow, and loses its compact, close-grained texture. This phase passes into a second, in which the rock is perceptibly porous, having a rough fracture

[1] *Trans.*, xxx., 415–416.

and a harsh 'feel,' and containing enough ocher to soil the fingers. In the next phase the ocher preponderates, but is held together by a more or less continuous skeleton of silica, although it can be readily removed with a pick. The final stage in the transition is the soft yellow-ocher, filling the veins, which crumbles on drying, and contains only a small proportion of silica in the form of sand-grains.

"The intermediate zone between the pure ocher and the quartzite is usually a few inches in thickness, although it may be several feet between the extremes, and, on the other hand, sometimes only a fraction of an inch."

Microscopic study of a large number of thin sections of the ocher-charged quartzite collected from all parts of the area discloses, with but few exceptions, either the former or the existing presence of pyrite. In many of the sections at least a part of the pyrite is entirely fresh and unaltered, but in a majority of them the pyrite has been completely oxidized, leaving the original space occupied by the mineral only partially filled, as a rule, by its alteration-product, iron oxide. Between these two extremes, of scant iron oxide partially lining the cavity and pseudomorphic limonite filling the entire cavity, all gradations are traced.

The full and accurate description quoted above from Hayes of the ocher-occurrence in the fresh quartzite in the section exposed at the wooden bridge over the Etowah river, similarly applies to the remaining exposures over the area studied by me, in which sections show the occurrence of ocher in the fresh rock.

Occurrence in the Residual Clays.—The area is one of profound atmospheric decay, and exposures of the fresh rock are rarely seen, except on the steeper ridge slopes and crests. The ocher cuts the enclosing clays in a very irregular manner, forming a series of irregular branching deposits which correspond to veins in the fresh rock. The ore-bodies narrow and widen, thin and thicken, throughout their extent. Irregularity results both as to the vertical and the lateral distribution of the deposits. The contact between the ocher-bodies and the sur-

rounding clays is never entirely sharp, but a more or less gradual transition from the clays to the pure ocher is usually shown. The ocher-charged clays at the point of contact lessen considsiderably in the ocher-content a short distance away, and is entirely absent from the clays at some distance from the point of contact. As in the case of the ocher-bodies in the fresh rock, the transition zone between the clay and the pure ocher is quite variable, from a few inches or less to as many feet between the extremes.

The field conditions make it entirely plain that the position of the ocher in the clays is in all respects similar to that in the fresh rock. Evidence pointing to leaching or concentration of these bodies upon weathering of the rock is lacking. Somewhat extensive mining on the properties of the Blue Ridge Ocher Company, the Cherokee Ocher & Barytes Company, and the American Ocher Company, affords the best opportunity for studying the mode of occurrence of the ocher in the residual clays.

Origin of the Ocher.

The mode of occurrence of the ocher when viewed in its relations to the character and structural conditions of the enclosing rock forms the strongest possible argument for the theory favoring its formation from solution. All evidence, both from field- and laboratory-study goes to prove that the deposition of the ocher has taken place, not by simple filling of cavities and fissures in the rock, but by a molecular replacement of the original rock. The principal evidence in proof of this is summed up as follows:

1. In nearly every instance of exposure of the fresh rock over the ocher-belt the rock is found to be extensively crushed and shattered and cut in all directions with lines of fracture, by compression. This mechanical action was more than probably accompanied by heat, and the zone of crushed rock afforded ready and natural passage-ways for underground circulating waters, both of which were conducive or favorable to increased chemical action.

2. The contact between the ocher and the surrounding quartzite is never sharp and distinct, but is marked by a gradual transition from the hard quartzite to the soft ore. The transition-zone between the hard quartzite and the soft ocher varies from a few inches to several feet in thickness between the two extremes.

3. The exceedingly irregular character of the ore-bodies and their distribution in the enclosing rock furnish further evidence. The shattered rock is cut in all directions by exceedingly irregular branching veins of the ocher, which narrow and widen, thin and thicken indiscriminately, without apparent regard to system or uniformity.

4. Microscopic study of the transition-portion of the rock makes plain the relations of the ocher to the quartz-rock and the mode of ore-occurrence in the rock. The iron oxide (ocher) usually cuts across the quartz-grains instead of lying between them. This replacement process is never complete, but all the ocher contains more or less free quartz-grains distributed through it. The grains are very irregular in outline, which distinguishes them from ordinary quartz- or sand-grains, and they were evidently formed from solution.

5. Finally, the replacement-hypothesis is strengthened by the general appearance of the rock which affords in places evidence of solution and redeposition of the silica. Small cavities are frequently observed penetrating the quartzite, and lined with very small crystals of quartz deposited from solution. Also, the skeleton of silica holding the ocher together and the sand-grains disseminated through the purer beds of soft ocher appear to have been derived by deposition from solution, rather than to be composed of grains of the original rock.

The source of the iron oxide, and the solution of the quartz of the rock and its replacement by the iron oxide (ocher) have been previously discussed in some detail by Hayes, [1] and need not be repeated here. After a microscopic study of a large number of thin sections of the ocher-charged and the ocher-

[1] *Trans.*, XXX., 403.

free quartzite, I feel reasonably certain that an additional source of the iron oxide not considered by Hayes, is derived from the oxidation of disseminated pyrite through the quartzite. The source of iron oxide from this direction may possibly have been of only secondary importance.

Economic Features.

Methods of Mining.

The ocher-deposits to be mined in the Cartersville district form extremely irregular branching veins, which intersect the rock in almost every direction. The ore-bodies may occur enclosed in the hard and fresh quartzite, or they may be entirely enclosed in the residual decay derived from the quartzite. The bodies of pure ocher are usually soft and clay-like in character, and the ore is easily mined with the pick and shovel. They are generally exposed along the slopes and summits of the quartzite hills and ridges.

On those properties in the district where systematic mining has been done, the method employed consists of tunnels driven into the ridge, from which drifts are worked at suitable points. In this way a number of levels have been worked, one above the other, on several of the properties. Occurrence of the ocher in the fresh rock, as on the Georgia Peruvian Ocher Company's property at the wooden bridge across the Etowah river, at times necessitates blasting. (See Fig. 4).

Timbering is necessary in the tunneling, as caving is apt to occur. The undergound-mining is also extensive enough to necessitate tramways and lights. The tram-cars are drawn in and out of the mines either by mules or by means of steam and cable. Both are in use in the Cartersville mines.

Preparation of the Ocher.

The only preparation necessary involves the separation of the ocher from its mechanically admixed impurities as mined, which consist principally of clay, sand, and manganese oxide. These are freed from the ocher by a process of washing in running water, floating, and settling of the ocher in vats, from which the water is evaporated.

With one exception, the form of washer in use at the different plants in the district is of the kind used in washing the manganese and brown iron-ores, known as the log-washer, and has been described by me in a former paper,[1] entitled "The Geologic Relations of the Manganese Ore-Deposits of Georgia."[2]

The form of washer in use at the Blue Ridge Ocher Company's plant was planned for the purpose of diminishing the grinding and rubbing action of the log-washer, and thereby decrease proportionately the resulting percentage of finely divided impurities, principally sand and manganese dioxide, which would be floated with the ocher. The washer consists of a V-shaped box about 7 ft. in length, 5 ft. high, and 3 ft. wide at the top. In the bottom of the box is fastened a 3-in. pipe with ⅛-in. perforations along the top at intervals of about 1.25 in. The water is introduced into this pipe, and passes into the box through the perforations in the pipe. Over this pipe revolves a shaft set with 1-in. pins so arranged that those of one row fall just halfway between those of the next, giving a spacing of 2-in. between pins, if they were aligned in the same row.

By this arrangement the ocher is sufficiently disintegrated without being subjected to the grinding and rubbing action of the ordinary log-washer. The water containing the suspended particles of ocher overflows at the top of the washer-box into a line of troughs, through which it passes into the settling-vats. The ocher is further purified by the settling of a portion of the impurities along the bottom of the troughs in transit to the vats. After the overflow becomes thin, showing that the ocher in the charge is about exhausted, a long narrow door at the bottom of the washer is raised and the sand, clay, etc., mixed with some ocher, are washed through and carried off in a trough as waste.

I am reliably informed by the manager of this plant that the washer of the size above stated easily handles from 25 to 30 tons of ocher per day of ten hours, and that all the necessary

[1] *Trans.*, xxxiv., p. 207.

[2] Reprint, *Bulletin Scientific Laboratories of Denison University*, 1904, Vol. XII, Art. X, pp. 146-198.

work, including cleaning of the troughs, etc., is readily performed by three ordinary laborers.

The ocher passes from the washer, through a line of troughs, into a series of settling-vats dug in the ground, and is exposed throughout the day to the direct heat of the sun. After it has settled, and as much as possible of the water siphoned off by rubber-hose, the remainder of the water is expelled by evaporation. As soon as it is stiff enough to be handled, the ocher is removed from the vats and placed on drying-racks under a shed where the drying-process is completed. (See Fig. 7). The time required for the evaporation of the water from the ocher in the vats sufficient to admit of handling will average about ten days in clear summer weather. It requires from eight to twelve days of similar weather to complete the drying on the racks before the ocher can be pulverized.

Evaporation is either by natural means—exposure to the heat of the sun—or by artificial means promoted by steam-heating. Several of the plants in the district are fully equipped for both natural and artificial evaporation. The artificial drying is in vats or tanks, arranged in series, in which iron-pipes are run at close intervals along the sides and bottoms for steam-heating. Drying by this method requires usually not longer than one or two days, when the ocher is ready to be removed to the racks and the drying continued for the usual time, from eight to twelve days, before it is dry enough to be pulverized. While the time is much shortened by the steam-drying over that of the natural evaporation by the sun, the ocher is less desirable than the sun-dried material; the reason for this being that near the pipes the heat is strong enough to dehydrate partially or calcine the ocher, changing its color from yellow to dark red. For this reason some plants in the district have not included an equipment for artificial drying.

After being thoroughly dried, the ocher is pulverized and packed under steam-pressure in barrels and bags of uniform size, ready for shipment.

Fig. 8 presents a view of the plant of the American Ocher

Company, two-and-a-half miles northeast of Cartersville. The drying-racks are shown in the rear of the main building.

Uses.

The principal use made of the Cartersville ocher at present is in the manufacture of linoleum and oil-cloths. For this consumption the principal markets are in England and Scotland, to which the bulk of the Cartersville product is exported. Some of it is used in the United States for a similar purpose. It is also used to a limited extent in the manufacture of paints. By calcining, the ocher is converted into a desirable dark red pigment.

Plate from not
for use
Watson